

What is claimed is:

1. A radio-wave arrival-direction estimating apparatus comprising:
 - an array antenna including a plurality of antenna elements;
 - a receiving unit for converting frequency of a **RF** signal
 - 5 received by each of the antenna elements in said array antenna, demodulating the converted signal, and outputting the demodulated signal;
 - an A/D converter for converting the demodulated signal to a complex digital signal;
 - a correlation matrix calculation unit for calculating a correlation matrix
 - 10 by correlation calculation of the complex digital signal between the antenna elements;
 - a noise spatial eigenmatrix calculation unit for calculating a noise spatial eigenmatrix by eigenvalue factorization of the correlation matrix, one of a row and a column of the noise spatial eigenmatrix being an eigenvector belonging to a
 - 15 noise eigen-space;
 - a triangular matrix calculation unit for factorizing a matrix including a product of the noise spatial eigenmatrix and a conjugated and transposed matrix of the noise spatial eigenmatrix to a product of one of an upper triangular matrix and a lower triangular matrix;
 - 20 an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix; and
 - an arrival-angle determination unit for determining an arrival angle
 - 25 based on the evaluation value from said arrival-angle evaluation unit.
2. A radio-wave arrival-direction estimating apparatus according to claim

1 further comprising a unitary transforming unit for unitary-transforming the correlation matrix, wherein

the plurality of antenna elements are arranged linearly at a constant interval, and

5 said noise spatial eigenmatrix calculation unit applies the eigenvalue factorization to the unitary-transformed correlation matrix.

3. A radio-wave arrival-direction estimating apparatus according to claim 1, wherein said triangular matrix calculation unit factorizes input matrix R to product $U^H U$ of upper triangular matrix U by cholesky factorization.

4. A radio-wave arrival-direction estimating apparatus according to claim 1, wherein said triangular matrix calculation unit factorizes input matrix R to product LL^H of lower triangular matrix L by cholesky factorization.

5. A radio-wave arrival-direction estimating apparatus according to claim 1, wherein said triangular matrix calculation unit factorizes an input matrix to product $U^H D U$ of upper triangular matrix U and diagonal matrix D by modified cholesky factorization.

6. A radio-wave arrival-direction estimating apparatus according to claim 1, wherein said triangular matrix calculation unit factorizes an input matrix to product LDL^H of lower triangular matrix L and diagonal matrix D by modified cholesky factorization.

7. A radio-wave arrival-direction estimating apparatus according to claim 1, wherein said correlation matrix calculation unit calculates a correlation matrix,

applies a spatial smoothing technique to the correlation matrix, and outputs a resultant matrix.

8. A radio-wave arrival-direction estimating apparatus according to claim
5 1, wherein

said array antenna includes a plurality of antenna elements arranged linearly at a constant interval, and

said arrival-angle evaluation unit comprises
a positive-region evaluation unit for calculating an evaluation value
10 of an arrival-angle evaluation function for positive angle θ with reference to a bore-sight direction of said array antenna, and

a negative-region evaluation unit for converting the evaluation value by the positive-region evaluation unit to an arrival-angle evaluation value for negative angle $(-\theta)$.

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9. A radio-wave arrival-direction estimating apparatus according to claim 1, wherein

said array antenna has a linear array shape, and

said arrival-angle evaluation unit sets an angle interval in an end fire
20 direction of said array antenna to be larger than an angle interval in a bore-sight direction, and calculates an evaluation value of an arrival-angle evaluation function.

10. A radio-wave arrival-direction estimating apparatus according to
25 claim 1, further comprising:

a high-accuracy arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function at an angle interval

smaller than an angle interval calculated by said arrival-angle evaluation unit, in a predetermined angle range around the arrival angle supplied from said arrival-angle determination unit; and

- 5 a high-accuracy arrival-angle determination unit for highly accurately determining an arrival angle based on the evaluation value by said high-accuracy arrival-angle evaluation unit.

11. A radio-wave arrival-direction estimating apparatus comprising:

- an array antenna including a plurality of antenna elements;
- 10 an intermediate-frequency receiving unit for performing frequency conversion and phase detection of a RF signal received by each of the antenna elements, and outputting an intermediate frequency signal;
- an intermediate-frequency A/D converter for converting the intermediate frequency signal to an intermediate-frequency digital signal;
- 15 a digital orthogonal wave detector for orthogonally demodulating the intermediate-frequency digital signal;
- a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;
- 20 a noise spatial eigenmatrix calculation unit for calculating a noise spatial eigenmatrix by eigenvalue factorization of the correlation matrix, one of a row and a column of the noise spatial eigenmatrix being an eigenvector belonging to a noise eigen-space;
- a triangular matrix calculation unit for factorizing a matrix including a
- 25 product of the noise spatial eigenmatrix and a conjugated and transposed matrix of the noise spatial eigenmatrix to a product of one of an upper triangular matrix and a lower triangular matrix;

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix; and

- 5 an arrival-angle determination unit for determining an arrival angle based on the evaluation value from said arrival-angle evaluation unit.

12. A radio-wave arrival-direction estimating apparatus comprising:

an array antenna including a plurality of antenna elements;

- 10 a receiving unit for converting frequency of a RF signal received by each of the antenna elements in said array antenna, demodulating the converted signal, and outputting the demodulated signal;

an A/D converter for converting the demodulated signal to a complex digital signal;

- 15 a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;

an inverse matrix calculation unit for calculating an inverse matrix of the correlation matrix;

- 20 a triangular matrix calculation unit for factorizing the inverse matrix to a product of one of an upper triangular matrix and a lower triangular matrix;

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix; and

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an arrival-angle determination unit for determining an arrival angle based on the evaluation value from said arrival-angle evaluation unit.

13. A radio-wave arrival-direction estimating apparatus according to claim 12 further comprising a unitary transforming unit for unitary-transforming the correlation matrix, wherein

5 the plurality of antenna elements are arranged linearly at a constant interval, and

 said inverse matrix calculation unit calculates an inverse matrix of the unitary-transformed correlation matrix.

10 14. A radio-wave arrival-direction estimating apparatus according to claim 12, wherein said triangular matrix calculation unit factorizes input matrix R to product $U^H U$ of upper triangular matrix U by cholesky factorization.

15 15. A radio-wave arrival-direction estimating apparatus according to claim 12, wherein said triangular matrix calculation unit factorizes input matrix R to product LL^H of lower triangular matrix L by cholesky factorization.

20 16. A radio-wave arrival-direction estimating apparatus according to claim 12, wherein said triangular matrix calculation unit factorizes an input matrix to product $U^H D U$ of upper triangular matrix U and diagonal matrix D by modified cholesky factorization.

25 17. A radio-wave arrival-direction estimating apparatus according to claim 12, wherein said triangular matrix calculation unit factorizes an input matrix to product LDL^H of lower triangular matrix L and diagonal matrix D by modified cholesky factorization.

18. A radio-wave arrival-direction estimating apparatus according to claim 12, wherein said correlation matrix calculation unit calculates a correlation matrix, applies a spatial smoothing technique to the correlation matrix, and outputs a resultant matrix.

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19. A radio-wave arrival-direction estimating apparatus according to claim 12, wherein

said array antenna includes a plurality of antenna elements arranged linearly at a constant interval, and

10 said arrival-angle evaluation unit comprises

a positive-region evaluation unit for calculating an evaluation value of an arrival-angle evaluation function for positive angle θ with reference to a bore-sight direction of said array antenna, and

a negative-region evaluation unit for converting the evaluation
15 value by the positive-region evaluation unit to an arrival-angle evaluation value for negative angle $(-\theta)$.

20. A radio-wave arrival-direction estimating apparatus according to claim 12, wherein

20 said array antenna has a linear array shape, and

said arrival-angle evaluation unit sets an angle interval in an end fire direction of said array antenna to be larger than an angle interval in a bore-sight direction, and calculates an evaluation value of an arrival-angle evaluation function.

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21. A radio-wave arrival-direction estimating apparatus according to claim 12, further comprising:

a high-accuracy arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function at an angle interval smaller than an angle interval calculated by said arrival-angle evaluation unit, in a predetermined angle range around the arrival angle supplied from said arrival-angle determination unit; and

a high-accuracy arrival-angle determination unit for highly accurately determining an arrival angle based on the evaluation value by said high-accuracy arrival-angle evaluation unit.

22. A radio-wave arrival-direction estimating apparatus comprising:

an array antenna including a plurality of antenna elements;

an intermediate-frequency receiving unit for performing frequency conversion and phase detection of a RF signal received by each of the antenna elements, and outputting an intermediate frequency signal;

an intermediate-frequency A/D converter for converting the intermediate frequency signal to an intermediate-frequency digital signal;

a digital orthogonal wave detector for orthogonally demodulating the intermediate-frequency digital signal;

a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;

an inverse matrix calculation unit for calculating an inverse matrix of the correlation matrix;

a triangular matrix calculation unit for factorizing the inverse matrix to a product of one of an upper triangular matrix and a lower triangular matrix;

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle

evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix; and

an arrival-angle determination unit for determining an arrival angle based on the evaluation value by said arrival-angle evaluation unit.

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23. A radio-wave arrival-direction estimating apparatus comprising:

an array antenna including a plurality of antenna elements;

a receiving unit for converting frequency of a ~~RF~~ signal received by each of the antenna elements in said array antenna, demodulating
10 the converted signal, and outputting the demodulated signal;

an A/D converter for converting the demodulated signal to a complex digital signal;

a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna
15 elements;

a triangular matrix calculation unit for factorizing the correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix;

an inverse matrix calculation unit for calculating an inverse matrix of the one of the upper triangular matrix and the lower triangular matrix;

20 an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the inverse matrix of the one of the upper triangular matrix and the lower triangular matrix; and

an arrival-angle determination unit for determining an arrival angle
25 based on the evaluation value by said arrival-angle evaluation unit.

24. A radio-wave arrival-direction estimating apparatus according to

claim 23 further comprising a unitary transforming unit for unitary-transforming the correlation matrix, wherein

the plurality of antenna elements are arranged linearly at a constant interval, and

5 said triangular matrix calculation unit factorizes the unitary-transformed correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix.

25. A radio-wave arrival-direction estimating apparatus according to
10 claim 23, wherein said triangular matrix calculation unit factorizes input matrix R to product $U^H U$ of upper triangular matrix U by cholesky factorization.

26. A radio-wave arrival-direction estimating apparatus according to
15 claim 23, wherein said triangular matrix calculation unit factorizes input matrix R to product LL^H of lower triangular matrix L by cholesky factorization.

27. A radio-wave arrival-direction estimating apparatus according to
claim 23, wherein said triangular matrix calculation unit factorizes an input
matrix to product $U^H D U$ of upper triangular matrix U and diagonal matrix D by
20 modified cholesky factorization.

28. A radio-wave arrival-direction estimating apparatus according to
claim 23, wherein said triangular matrix calculation unit factorizes an input
matrix to product LDL^H of lower triangular matrix L and diagonal matrix D by
25 modified cholesky factorization.

29. A radio-wave arrival-direction estimating apparatus according to

claim 23, wherein said correlation matrix calculation unit calculates a correlation matrix, applies a spatial smoothing technique to the correlation matrix, and outputs a resultant matrix.

5 30. A radio-wave arrival-direction estimating apparatus according to claim 23, wherein

 said array antenna includes a plurality of antenna elements arranged linearly at a constant interval, and

 said arrival-angle evaluation unit comprises

10 a positive-region evaluation unit for calculating an evaluation value of an arrival-angle evaluation function for positive angle θ with reference to a bore-sight direction of said array antenna, and

 a negative-region evaluation unit for converting the evaluation value by the positive-region evaluation unit to an arrival-angle evaluation value
15 for negative angle $(-\theta)$.

 31. A radio-wave arrival-direction estimating apparatus according to claim 23, wherein

 said array antenna has a linear array shape, and

20 said arrival-angle evaluation unit sets an angle interval in an end fire direction of said array antenna to be larger than an angle interval in a bore-sight direction, and calculates an evaluation value of an arrival-angle evaluation function.

25 32. A radio-wave arrival-direction estimating apparatus according to claim 23, further comprising:

 a high-accuracy arrival-angle evaluation unit for calculating an

evaluation value of an arrival-angle evaluation function at an angle interval smaller than an angle interval calculated by said arrival-angle evaluation unit, in a predetermined angle range around the arrival angle supplied from said arrival-angle determination unit; and

- 5 a high-accuracy arrival-angle determination unit for highly accurately determining an arrival angle based on the evaluation value by said high-accuracy arrival-angle evaluation unit.

33. A radio-wave arrival-direction estimating apparatus comprising:

- 10 an array antenna including a plurality of antenna elements;
 an intermediate-frequency receiving unit for performing frequency conversion and phase detection of a RF signal received by each of the antenna elements, and outputting an intermediate frequency signal;
 an intermediate-frequency A/D converter for converting the intermediate
 15 frequency signal to an intermediate-frequency digital signal;
 a digital orthogonal wave detector for orthogonally demodulating the intermediate-frequency digital signal;
 a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna
 20 elements;
 a triangular matrix calculation unit for factorizing the correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix;
 an inverse matrix calculation unit for calculating an inverse matrix of the one of an upper triangular matrix and a lower triangular matrix;
 25 an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the inverse matrix of the one of the

upper triangular matrix and the lower triangular matrix; and

an arrival-angle determination unit for determining an arrival angle based on the evaluation value by said arrival-angle evaluation unit.

5 34. A radio-wave arrival-direction estimating apparatus comprising:

an array antenna including a plurality of antenna elements;

a receiving unit for converting frequency of a **RF** signal received by each of the antenna elements in said array antenna, demodulating the converted signal, and outputting the demodulated signal;

10 an A/D converter for converting the demodulated signal to a complex digital signal;

a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;

15 a triangular matrix calculation unit for factorizing the correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix;

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix

20 and the lower triangular matrix; and

an arrival-angle determination unit for determining an arrival angle based on the evaluation value by said arrival-angle evaluation unit.

25 35. A radio-wave arrival-direction estimating apparatus according to claim 34 further comprising a unitary transforming unit for unitary-transforming the correlation matrix, wherein

the plurality of antenna elements are arranged linearly at a constant

interval, and

said triangular matrix calculation unit factorizes the unitary-transformed correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix.

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36. A radio-wave arrival-direction estimating apparatus according to claim 34, wherein said triangular matrix calculation unit factorizes input matrix R to product $U^H U$ of upper triangular matrix U by cholesky factorization.

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37. A radio-wave arrival-direction estimating apparatus according to claim 34, wherein said triangular matrix calculation unit factorizes input matrix R to product LL^H of lower triangular matrix L by cholesky factorization.

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38. A radio-wave arrival-direction estimating apparatus according to claim 34, wherein said triangular matrix calculation unit factorizes an input matrix to product $U^H D U$ of upper triangular matrix U and diagonal matrix D by modified cholesky factorization.

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39. A radio-wave arrival-direction estimating apparatus according to claim 34, wherein said triangular matrix calculation unit factorizes an input matrix to product LDL^H of lower triangular matrix L and diagonal matrix D by modified cholesky factorization.

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40. A radio-wave arrival-direction estimating apparatus according to claim 34, wherein said correlation matrix calculation unit calculates a correlation matrix, applies a spatial smoothing technique to the correlation matrix, and outputs a resultant matrix.

41. A radio-wave arrival-direction estimating apparatus according to claim 34, wherein

said array antenna includes a plurality of antenna elements arranged
5 linearly at a constant interval, and

said arrival-angle evaluation unit comprises

a positive-region evaluation unit for calculating an evaluation value of an arrival-angle evaluation function for positive angle θ with reference to a bore-sight direction of said array antenna, and

10 a negative-region evaluation unit for converting the evaluation value by the positive-region evaluation unit to an arrival-angle evaluation value for negative angle $(-\theta)$.

42. A radio-wave arrival-direction estimating apparatus according to
15 claim 34, wherein

said array antenna has a linear array shape, and

said arrival-angle evaluation unit sets an angle interval in an end fire direction of said array antenna to be larger than an angle interval in a bore-sight direction, and calculates an evaluation value of an arrival-angle evaluation
20 function.

43. A radio-wave arrival-direction estimating apparatus according to claim 34, further comprising:

a high-accuracy arrival-angle evaluation unit for calculating an
25 evaluation value of an arrival-angle evaluation function at an angle interval smaller than an angle interval calculated by said arrival-angle evaluation unit, in a predetermined angle range around the arrival angle supplied from said arrival-

angle determination unit; and

a high-accuracy arrival-angle determination unit for highly accurately determining an arrival angle based on the evaluation value by said high-accuracy arrival-angle evaluation unit.

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44. A radio-wave arrival-direction estimating apparatus comprising:

an array antenna including a plurality of antenna elements;

an intermediate-frequency receiving unit for performing frequency conversion and phase detection of a RF signal received by each of the antenna elements, and outputting an intermediate frequency signal;

10 an intermediate-frequency A/D converter for converting the intermediate frequency signal to an intermediate-frequency digital signal;

a digital orthogonal wave detector for orthogonally demodulating the intermediate-frequency digital signal;

15 a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;

a triangular matrix calculation unit for factorizing the correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix;

20 an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix; and

an arrival-angle determination unit for determining an arrival angle based on the evaluation value by said arrival-angle evaluation unit.

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45. A radio-wave arrival-direction estimating apparatus comprising:

- an array antenna including a plurality of antenna elements;
a receiving unit for converting frequency of a **RF** signal received by each of the antenna elements in said array antenna, demodulating the converted signal, and outputting the demodulated signal;
5 an A/D converter for converting the demodulated signal to a complex digital signal;
a correlation vector calculation unit for calculating a correlation vector by correlation calculation between a reference antenna element and another antenna element, the reference antenna element corresponding to a selected
10 complex digital signal;
an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the correlation vector; and
an arrival-angle determination unit for determining an arrival angle
15 based on the evaluation value by said arrival-angle evaluation unit.

46. A radio-wave arrival-direction estimating apparatus according to claim 45 further comprising a unitary transforming unit for unitary-transforming the correlation vector, wherein
20 the plurality of antenna elements are arranged linearly at a constant interval, and
said arrival-angle evaluation unit calculates an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the unitary-transformed correlation
25 vector.

47. A radio-wave arrival-direction estimating apparatus according to

claim 45, wherein

said array antenna includes a plurality of antenna elements arranged linearly at a constant interval, and

said arrival-angle evaluation unit comprises

5 a positive-region evaluation unit for calculating an evaluation value of an arrival-angle evaluation function for positive angle θ with reference to a bore-sight direction of said array antenna, and

a negative-region evaluation unit for converting the evaluation value by the positive-region evaluation unit to an arrival-angle evaluation value
10 for negative angle $(-\theta)$.

48. A radio-wave arrival-direction estimating apparatus according to claim 45, wherein

said array antenna has a linear array shape, and

15 said arrival-angle evaluation unit sets an angle interval in an end fire direction of said array antenna to be larger than an angle interval in a bore-sight direction, and calculates an evaluation value of an arrival-angle evaluation function.

20 49. A radio-wave arrival-direction estimating apparatus according to claim 45, further comprising:

a high-accuracy arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function at an angle interval smaller than an angle interval calculated by said arrival-angle evaluation unit, in
25 a predetermined angle range around the arrival angle supplied from said arrival-angle determination unit; and

a high-accuracy arrival-angle determination unit for highly accurately

determining an arrival angle based on the evaluation value by said high-accuracy arrival-angle evaluation unit.

50. A radio-wave arrival-direction estimating apparatus comprising:
- 5 an array antenna including a plurality of antenna elements;
- an intermediate-frequency receiving unit for performing frequency conversion and phase detection of a RF signal received by each of the antenna elements, and outputting an intermediate frequency signal;
- an intermediate-frequency A/D converter for converting the intermediate
- 10 frequency signal to an intermediate-frequency digital signal;
- a digital orthogonal wave detector for orthogonally demodulating the intermediate-frequency digital signal;
- a correlation vector calculation unit for calculating a correlation vector by correlation calculation between a reference antenna element and another
- 15 antenna element, the reference antenna element corresponding to a selected complex digital signal;
- an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the correlation vector; and
- 20 an arrival-angle determination unit for determining an arrival angle based on the evaluation value by said arrival-angle evaluation unit.

51. A directivity variable receiver comprising:
- a radio-wave arrival-direction estimating apparatus including:
- 25 an array antenna having a plurality of antenna elements;
- a receiving unit for converting frequency of a RF signal received by each of the antenna elements in the array antenna, demodulating the

converted signal, and outputting the demodulated signal;

an A/D converter for converting the demodulated signal to a complex digital signal;

a correlation vector calculation unit for calculating a correlation
5 vector by correlation calculation between a reference antenna element and
another antenna element, the reference antenna element corresponding to a
selected complex digital signal;

an arrival-angle evaluation unit for calculating an evaluation value
of an arrival-angle evaluation function every predetermined angle, the arrival-
10 angle evaluation function being expressed using the correlation vector; and

an arrival-angle determination unit for determining an arrival angle
based on the evaluation value by the arrival-angle evaluation unit;

a plurality of sector antennas having different main beam directions;

a sector control unit for outputting a sector control signal used for
15 selecting one sector antenna from said plurality of sector antennas, the selected
sector antenna having a beam direction in a direction estimated by said radio-
wave arrival-direction estimating apparatus;

a sector switch for alternatively coupling the sector antenna based on the
sector control signal; and

20 a receiving unit for demodulating an output signal of said sector switch.

52. A directivity variable receiver according to claim 51, wherein

the plurality of antenna elements are arranged linearly at a constant
interval,

25 said radio-wave arrival-direction estimating apparatus further
comprises a unitary transforming unit for unitary-transforming the correlation
vector, and

the arrival-angle evaluation unit calculates an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the unitary-transformed correlation vector.

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53. A directivity variable receiver according to claim 51,
wherein said radio-wave arrival-direction estimating apparatus comprises:

an array antenna including a plurality of antenna elements;

10 a receiving unit for converting frequency of a **RF** signal received by each of the antenna elements in the array antenna, demodulating the converted signal, and outputting the demodulated signal;

an A/D converter for converting the demodulated signal to a complex digital signal;

15 a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;

a noise spatial eigenmatrix calculation unit for calculating a noise spatial eigenmatrix by eigenvalue factorization of the correlation matrix, one of a row and a column of the noise spatial eigenmatrix being an eigenvector belonging to a noise eigen-space;

20 a triangular matrix calculation unit for factorizing a matrix including a product of the noise spatial eigenmatrix and a conjugated and transposed matrix of the noise spatial eigenmatrix to a product of one of an upper triangular matrix and a lower triangular matrix; and

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle

evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix.

54. A directivity variable receiver according to claim 53, wherein

5 the plurality of antenna elements are arranged linearly at a constant interval,

said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation matrix, and

10 the noise spatial eigenmatrix calculation unit applies the eigenvalue factorization to the unitary-transformed correlation matrix.

55. A directivity variable receiver according to claim 51,

15 wherein said radio-wave arrival-direction estimating apparatus comprises:

an array antenna including a plurality of antenna elements;

a receiving unit for converting frequency of a RF signal received by each of the antenna elements in the array antenna, demodulating the converted signal, and outputting the demodulated signal;

20 an A/D converter for converting the demodulated signal to a complex digital signal;

a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;

25 an inverse matrix calculation unit for calculating an inverse matrix of the correlation matrix;

a triangular matrix calculation unit for factorizing the inverse matrix

to a product of one of an upper triangular matrix and a lower triangular matrix;

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix; and

an arrival-angle determination unit for determining an arrival angle based on the evaluation value by the arrival-angle evaluation unit.

56. A directivity variable receiver according to claim 55, wherein the plurality of antenna elements are arranged linearly at a constant interval,

said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation matrix, and

the inverse matrix calculation unit calculates an inverse matrix of the unitary-transformed correlation matrix.

57. A directivity variable receiver according to claim 51, wherein said radio-wave arrival-direction estimating apparatus comprises:

an array antenna including a plurality of antenna elements;
a receiving unit for converting frequency of a **RF** signal received by each of the antenna elements in the array antenna, demodulating the converted signal, and outputting the demodulated signal;

an A/D converter for converting the demodulated signal to a complex digital signal;

a correlation matrix calculation unit for calculating a correlation

matrix by correlation calculation of the complex digital signal between the antenna elements;

a triangular matrix calculation unit for factorizing the correlation matrix to a product of one of an upper triangular matrix and a lower triangular
5 matrix;

an inverse matrix calculation unit for calculating an inverse matrix of the one of an upper triangular matrix and a lower triangular matrix;

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-
10 angle evaluation function being expressed using the inverse matrix of the one of the upper triangular matrix and the lower triangular matrix; and

an arrival-angle determination unit for determining an arrival angle based on the evaluation value by the arrival-angle evaluation unit.

15 58. A directivity variable receiver according to claim 57, wherein

the plurality of antenna elements are arranged linearly at a constant interval,

said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation
20 matrix, and

the triangular matrix calculation unit factorizes the unitary-transformed correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix

25 59. A directivity variable receiver according to claim 51,

wherein said radio-wave arrival-direction estimating apparatus comprises:

an array antenna including a plurality of antenna elements;

a receiving unit for converting frequency of a RF signal received by each of the antenna elements in the array antenna, demodulating the converted signal, and outputting the demodulated signal;

5 an A/D converter for converting the demodulated signal to a complex digital signal;

a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;

10 a triangular matrix calculation unit for factorizing the correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix;

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix; and

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an arrival-angle determination unit for determining an arrival angle based on the evaluation value by the arrival-angle evaluation unit.

20 60. A directivity variable receiver according to claim 59, wherein

the plurality of antenna elements are arranged linearly at a constant interval,

said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation matrix, and

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the triangular matrix calculation unit factorizes the unitary-transformed correlation matrix to a product of one of an upper triangular matrix and a lower

triangular matrix

61. A directivity variable receiver comprising:

a radio-wave arrival-direction estimating apparatus including:

5 an array antenna having a plurality of antenna elements;

a receiving unit for converting frequency of a RF signal received by each of the antenna elements in the array antenna, demodulating the converted signal, and outputting the demodulated signal;

10 an A/D converter for converting the demodulated signal to a complex digital signal;

a correlation vector calculation unit for calculating a correlation vector by correlation calculation between a reference antenna element and another antenna element, the reference antenna element corresponding to a selected complex digital signal;

15 an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the correlation vector; and

an arrival-angle determination unit for determining an arrival angle based on the evaluation value by the arrival-angle evaluation unit;

20 a directivity control unit for assigning a complex weight to the demodulated signal and combines the signals with each other so as to generate directivity of the array antenna to an arrival direction of the radio-wave arrival-direction estimating apparatus; and

25 a receiving unit for demodulating an output signal of the directivity control unit.

62. A directivity variable receiver according to claim 61, wherein

the plurality of antenna elements are arranged linearly at a constant interval,

said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation
5 vector, and

the arrival-angle evaluation unit calculates an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the unitary-transformed correlation vector.

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63. A directivity variable receiver according to claim 61,

wherein said radio-wave arrival-direction estimating apparatus comprises:

an array antenna including a plurality of antenna elements;
15 a receiving unit for converting frequency of a RF signal received by each of the antenna elements in the array antenna, demodulating the converted signal, and outputting the demodulated signal;

an A/D converter for converting the demodulated signal to a complex digital signal;

20 a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;

a noise spatial eigenmatrix calculation unit for calculating a noise spatial eigenmatrix by eigenvalue factorization of the correlation matrix, one of a
25 row and a column of the noise spatial eigenmatrix being an eigenvector belonging to a noise eigen-space;

a triangular matrix calculation unit for factorizing a matrix including a

product of the noise spatial eigenmatrix and a conjugated and transposed matrix of the noise spatial eigenmatrix to a product of one of an upper triangular matrix and a lower triangular matrix; and

an arrival-angle evaluation unit for calculating an evaluation value of
 5 an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix.

64. A directivity variable receiver according to claim 63, wherein
 10 the plurality of antenna elements are arranged linearly at a constant interval,
 said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation matrix, and
 15 the noise spatial eigenmatrix calculation unit applies the eigenvalue factorization to the unitary-transformed correlation matrix.

65. A directivity variable receiver according to claim 61,
 wherein said radio-wave arrival-direction estimating apparatus
 20 comprises:
 an array antenna including a plurality of antenna elements;
 a receiving unit for converting frequency of a RF signal received by each of the antenna elements in the array antenna, demodulating the converted signal, and outputting the demodulated signal;
 25 an A/D converter for converting the demodulated signal to a complex digital signal;
 a correlation matrix calculation unit for calculating a correlation

matrix by correlation calculation of the complex digital signal between the antenna elements;

an inverse matrix calculation unit for calculating an inverse matrix of the correlation matrix;

5 a triangular matrix calculation unit for factorizing the inverse matrix to a product of one of an upper triangular matrix and a lower triangular matrix;

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular
10 matrix and the lower triangular matrix; and

an arrival-angle determination unit for determining an arrival angle based on the evaluation value by the arrival-angle evaluation unit.

66. A directivity variable receiver according to claim 65, wherein
15 the plurality of antenna elements are arranged linearly at a constant interval,

said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation matrix, and

20 the inverse matrix calculation unit calculates an inverse matrix of the unitary-transformed correlation matrix.

67. A directivity variable receiver according to claim 61,
wherein said radio-wave arrival-direction estimating apparatus
25 comprises:

an array antenna including a plurality of antenna elements;

a receiving unit for converting frequency of a **RF** signal

received by each of the antenna elements in the array antenna, demodulating the converted signal, and outputting the demodulated signal;

an A/D converter for converting the demodulated signal to a complex digital signal;

5 a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;

 a triangular matrix calculation unit for factorizing the correlation matrix to a product of one of an upper triangular matrix and a lower triangular
10 matrix;

 an inverse matrix calculation unit for calculating an inverse matrix of the one of an upper triangular matrix and a lower triangular matrix;

 an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-
15 angle evaluation function being expressed using the inverse matrix of the one of the upper triangular matrix and the lower triangular matrix; and

 an arrival-angle determination unit for determining an arrival angle based on the evaluation value by the arrival-angle evaluation unit.

20 68. A directivity variable receiver according to claim 67, wherein

 the plurality of antenna elements are arranged linearly at a constant interval,

 said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation
25 matrix, and

 the triangular matrix calculation unit factorizes the unitary-transformed correlation matrix to a product of one of an upper triangular matrix and a lower

triangular matrix

69. A directivity variable receiver according to claim 61,

wherein said radio-wave arrival-direction estimating apparatus
5 comprises:

an array antenna including a plurality of antenna elements;

a receiving unit for converting frequency of a RF signal
received by each of the antenna elements in the array antenna, demodulating the
converted signal, and outputting the demodulated signal;

10 an A/D converter for converting the demodulated signal to a complex
digital signal;

a correlation matrix calculation unit for calculating a correlation
matrix by correlation calculation of the complex digital signal between the
antenna elements;

15 a triangular matrix calculation unit for factorizing the correlation
matrix to a product of one of an upper triangular matrix and a lower triangular
matrix;

an arrival-angle evaluation unit for calculating an evaluation value of
an arrival-angle evaluation function every predetermined angle, the arrival-
20 angle evaluation function being expressed using the one of the upper triangular
matrix and the lower triangular matrix; and

an arrival-angle determination unit for determining an arrival angle
based on the evaluation value by the arrival-angle evaluation unit.

25 70. A directivity variable receiver according to claim 69, wherein

the plurality of antenna elements are arranged linearly at a constant
interval,

said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation matrix, and

the triangular matrix calculation unit factorizes the unitary-transformed correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix

71. A directivity variable transmitter comprising:

a radio-wave arrival-direction estimating apparatus including:

10 an array antenna having a plurality of antenna elements;

a receiving unit for converting frequency of a RF signal received by each of the antenna elements in the array antenna, demodulating the converted signal, and outputting the demodulated signal;

15 an A/D converter for converting the demodulated signal to a complex digital signal;

a correlation vector calculation unit for calculating a correlation vector by correlation calculation between a reference antenna element and another antenna element, the reference antenna element corresponding to a selected complex digital signal;

20 an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the correlation vector; and

an arrival-angle determination unit for determining an arrival angle based on the evaluation value by the arrival-angle evaluation unit;

25 a plurality of sector antennas having different main beam directions;

a sector control unit for outputting a sector control signal used for selecting one sector antenna from said plurality of sector antennas, the selected

sector antenna having a beam direction in a direction estimated by said radio-wave arrival-direction estimating apparatus;

a sector switch for alternatively coupling the sector antenna based on the sector control signal; and

5 a transmitting unit for transmitting a modulated signal after frequency conversion from said sector antennas.

72. A directivity variable transmitter according to claim 71, wherein
the plurality of antenna elements are arranged linearly at a constant
10 interval,

said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation vector, and

the arrival-angle evaluation unit calculates an evaluation value of an
15 arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the unitary-transformed correlation vector.

73. A directivity variable transmitter according to claim 71,
20 wherein said radio-wave arrival-direction estimating apparatus comprises:

an array antenna including a plurality of antenna elements;

a receiving unit for converting frequency of a RF signal
received by each of the antenna elements in the array antenna, demodulating the
25 converted signal, and outputting the demodulated signal;

an A/D converter for converting the demodulated signal to a complex digital signal;

a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;

a noise spatial eigenmatrix calculation unit for calculating a noise spatial eigenmatrix by eigenvalue factorization of the correlation matrix, one of a row and a column of the noise spatial eigenmatrix being an eigenvector belonging to a noise eigen-space;

a triangular matrix calculation unit for factorizing a matrix including a product of the noise spatial eigenmatrix and a conjugated and transposed matrix of the noise spatial eigenmatrix to a product of one of an upper triangular matrix and a lower triangular matrix; and

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix.

74. A directivity variable transmitter according to claim 73, wherein

the plurality of antenna elements are arranged linearly at a constant interval,

said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation matrix, and

the noise spatial eigenmatrix calculation unit applies the eigenvalue factorization to the unitary-transformed correlation matrix.

75. A directivity variable transmitter according to claim 71,

wherein said radio-wave arrival-direction estimating apparatus

comprises:

- an array antenna including a plurality of antenna elements;
- a receiving unit for converting frequency of a **RF** signal received by each of the antenna elements in the array antenna, demodulating the converted signal, and outputting the demodulated signal;
- an A/D converter for converting the demodulated signal to a complex digital signal;
- a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;
- an inverse matrix calculation unit for calculating an inverse matrix of the correlation matrix;
- a triangular matrix calculation unit for factorizing the inverse matrix to a product of one of an upper triangular matrix and a lower triangular matrix;
- an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix; and
- an arrival-angle determination unit for determining an arrival angle based on the evaluation value by the arrival-angle evaluation unit.

76. A directivity variable transmitter according to claim 75, wherein the plurality of antenna elements are arranged linearly at a constant interval,
- said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation matrix, and

the inverse matrix calculation unit calculates an inverse matrix of the unitary-transformed correlation matrix.

77. A directivity variable transmitter according to claim 71,

5 wherein said radio-wave arrival-direction estimating apparatus comprises:

an array antenna including a plurality of antenna elements;

a receiving unit for converting frequency of a ~~radio~~ RF signal received by each of the antenna elements in the array antenna, demodulating the converted signal, and outputting the demodulated signal;

10 an A/D converter for converting the demodulated signal to a complex digital signal;

a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;

15 a triangular matrix calculation unit for factorizing the correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix;

an inverse matrix calculation unit for calculating an inverse matrix of the one of an upper triangular matrix and a lower triangular matrix;

20 an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the inverse matrix of the one of the upper triangular matrix and the lower triangular matrix; and

25 an arrival-angle determination unit for determining an arrival angle based on the evaluation value by the arrival-angle evaluation unit.

78. A directivity variable transmitter according to claim 77, wherein

the plurality of antenna elements are arranged linearly at a constant interval,

said radio-wave arrival-direction estimating apparatus further
5 comprises a unitary transforming unit for unitary-transforming the correlation matrix, and

the triangular matrix calculation unit factorizes the unitary-transformed correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix

10

79. A directivity variable transmitter according to claim 71,

wherein said radio-wave arrival-direction estimating apparatus comprises:

an array antenna including a plurality of antenna elements;

15 a receiving unit for converting frequency of a RF signal received by each of the antenna elements in the array antenna, demodulating the converted signal, and outputting the demodulated signal;

an A/D converter for converting the demodulated signal to a complex digital signal;

20 a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;

a triangular matrix calculation unit for factorizing the correlation matrix to a product of one of an upper triangular matrix and a lower triangular
25 matrix;

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-

angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix; and

an arrival-angle determination unit for determining an arrival angle based on the evaluation value by the arrival-angle evaluation unit.

5

80. A directivity variable transmitter according to claim 79, wherein

the plurality of antenna elements are arranged linearly at a constant interval,

10 said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation matrix, and

the triangular matrix calculation unit factorizes the unitary-transformed correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix

15

81. A directivity variable transmitter comprising:

a radio-wave arrival-direction estimating apparatus including:

an array antenna having a plurality of antenna elements;

20 a receiving unit for converting frequency of a RF signal received by each of the antenna elements in the array antenna, demodulating the converted signal, and outputting the demodulated signal;

an A/D converter for converting the demodulated signal to a complex digital signal;

25 a correlation vector calculation unit for calculating a correlation vector by correlation calculation between a reference antenna element and another antenna element, the reference antenna element corresponding to a selected complex digital signal;

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the correlation vector; and

- an arrival-angle determination unit for determining an arrival angle
- 5 based on the evaluation value by the arrival-angle evaluation unit;
- a transmitting unit for generating a transmitted signal;
- a directivity control unit for assigning a complex weight to the transmitted signal so as to generate antenna directivity to an arrival direction determined by the radio-wave arrival-direction estimating apparatus;
- 10 a transmitting unit for converting frequency of an output from said directivity control unit; and
- an array antenna for transmitting an output from said transmitting unit.

82. A directivity variable transmitter according to claim 81, wherein
- 15 the plurality of antenna elements are arranged linearly at a constant interval,
 - said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation vector, and
 - 20 the arrival-angle evaluation unit calculates an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the unitary-transformed correlation vector.

83. A directivity variable transmitter according to claim 81,
- 25 wherein said radio-wave arrival-direction estimating apparatus comprises:

an array antenna including a plurality of antenna elements;
 a receiving unit for converting frequency of a **RF** signal
 received by each of the antenna elements in the array antenna, demodulating the
 converted signal, and outputting the demodulated signal;
 5 an A/D converter for converting the demodulated signal to a complex
 digital signal;
 a correlation matrix calculation unit for calculating a correlation
 matrix by correlation calculation of the complex digital signal between the
 antenna elements;
 10 a noise spatial eigenmatrix calculation unit for calculating a noise
 spatial eigenmatrix by eigenvalue factorization of the correlation matrix, one of a
 row and a column of the noise spatial eigenmatrix being an eigenvector belonging
 to a noise eigen-space;
 a triangular matrix calculation unit for factorizing a matrix including a
 15 product of the noise spatial eigenmatrix and a conjugated and transposed matrix
 of the noise spatial eigenmatrix to a product of one of an upper triangular matrix
 and a lower triangular matrix; and
 an arrival-angle evaluation unit for calculating an evaluation value of an
 arrival-angle evaluation function every predetermined angle, the arrival-angle
 20 evaluation function being expressed using the one of the upper triangular matrix
 and the lower triangular matrix.

84. A directivity variable transmitter according to claim 83, wherein
 the plurality of antenna elements are arranged linearly at a constant
 25 interval,
 said radio-wave arrival-direction estimating apparatus further
 comprises a unitary transforming unit for unitary-transforming the correlation

matrix, and

the noise spatial eigenmatrix calculation unit applies the eigenvalue factorization to the unitary-transformed correlation matrix.

- 5 85. A directivity variable transmitter according to claim 81,
 wherein said radio-wave arrival-direction estimating apparatus
 comprises:
- an array antenna including a plurality of antenna elements;
 - a receiving unit for converting frequency of a **RF** signal
 - 10 received by each of the antenna elements in the array antenna, demodulating the
 converted signal, and outputting the demodulated signal;
 - an A/D converter for converting the demodulated signal to a complex
 digital signal;
 - a correlation matrix calculation unit for calculating a correlation
 - 15 matrix by correlation calculation of the complex digital signal between the
 antenna elements;
 - an inverse matrix calculation unit for calculating an inverse matrix of
 the correlation matrix;
 - a triangular matrix calculation unit for factorizing the inverse matrix
 - 20 to a product of one of an upper triangular matrix and a lower triangular matrix;
 - an arrival-angle evaluation unit for calculating an evaluation value of
 an arrival-angle evaluation function every predetermined angle, the arrival-
 angle evaluation function being expressed using the one of the upper triangular
 matrix and the lower triangular matrix; and
 - 25 an arrival-angle determination unit for determining an arrival angle
 based on the evaluation value by the arrival-angle evaluation unit.

86. A directivity variable transmitter according to claim 85, wherein
the plurality of antenna elements are arranged linearly at a constant
interval,

said radio-wave arrival-direction estimating apparatus further
5 comprises a unitary transforming unit for unitary-transforming the correlation
matrix, and

the inverse matrix calculation unit calculates an inverse matrix of the
unitary-transformed correlation matrix.

10 87. A directivity variable transmitter according to claim 81,
wherein said radio-wave arrival-direction estimating apparatus
comprises:

an array antenna including a plurality of antenna elements;

a receiving unit for converting frequency of a RF signal
15 received by each of the antenna elements in the array antenna, demodulating the
converted signal, and outputting the demodulated signal;

an A/D converter for converting the demodulated signal to a complex
digital signal;

a correlation matrix calculation unit for calculating a correlation
20 matrix by correlation calculation of the complex digital signal between the
antenna elements;

a triangular matrix calculation unit for factorizing the correlation
matrix to a product of one of an upper triangular matrix and a lower triangular
matrix;

25 an inverse matrix calculation unit for calculating an inverse matrix of
the one of the upper triangular matrix and the lower triangular matrix;

an arrival-angle evaluation unit for calculating an evaluation value of

an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the inverse matrix of the one of the upper triangular matrix and the lower triangular matrix; and

an arrival-angle determination unit for determining an arrival angle
 5 based on the evaluation value by the arrival-angle evaluation unit.

88. A directivity variable transmitter according to claim 87, wherein

the plurality of antenna elements are arranged linearly at a constant interval,

10 said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation matrix, and

the triangular matrix calculation unit factorizes the unitary-transformed correlation matrix to a product of one of an upper triangular matrix and a lower
 15 triangular matrix

89. A directivity variable transmitter according to claim 81,

wherein said radio-wave arrival-direction estimating apparatus comprises:

20 an array antenna including a plurality of antenna elements;

a receiving unit for converting frequency of a RF signal received by each of the antenna elements in the array antenna, demodulating the converted signal, and outputting the demodulated signal;

an A/D converter for converting the demodulated signal to a complex
 25 digital signal;

a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the

antenna elements;

a triangular matrix calculation unit for factorizing the correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix;

5 an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix; and

an arrival-angle determination unit for determining an arrival angle
10 based on the evaluation value by the arrival-angle evaluation unit.

90. A directivity variable transmitter according to claim 89, wherein

the plurality of antenna elements are arranged linearly at a constant interval,

15 said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation matrix, and

the triangular matrix calculation unit factorizes the unitary-transformed correlation matrix to a product of one of an upper triangular matrix and a lower
20 triangular matrix

91. A directivity variable transceiver comprising:

a radio-wave arrival-direction estimating apparatus including:

an array antenna having a plurality of antenna elements;

25 a receiving unit for converting frequency of a **RF** signal received by each of the antenna elements in the array antenna, demodulating the converted signal, and outputting the demodulated signal;

an A/D converter for converting the demodulated signal to a complex digital signal;

a correlation vector calculation unit for calculating a correlation vector by correlation calculation between a reference antenna element and
 5 another antenna element, the reference antenna element corresponding to a selected complex digital signal;

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle; the arrival-angle evaluation function being expressed using the correlation vector; and

10 an arrival-angle determination unit for determining an arrival angle based on the evaluation value by the arrival-angle evaluation unit;

a plurality of sector antennas having different main beam directions;

a sector control unit for outputting a sector control signal used for selecting one sector antenna from said plurality of sector antennas, the selected
 15 sector antenna having a beam direction in a direction estimated by said radio-wave arrival-direction estimating apparatus;

a sector switch for alternatively coupling the sector antenna based on the sector control signal;

a receiving unit for performing demodulation;

20 a transmitting unit for performing transmission; and

a switch coupled to the sector antenna for feeding an signal supplied from the selected sector antenna into said receiving unit or for outputting a transmitted signal from said transmitting unit through the selected sector antenna.

25

92. A directivity variable transceiver according to claim 91, wherein

the plurality of antenna elements are arranged linearly at a constant

interval,

said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation vector, and

5 the arrival-angle evaluation unit calculates an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the unitary-transformed correlation vector.

10 93. A directivity variable transceiver according to claim 91,

wherein said radio-wave arrival-direction estimating apparatus comprises:

an array antenna including a plurality of antenna elements;

15 a receiving unit for converting frequency of a **RF** signal received by each of the antenna elements in the array antenna, demodulating the converted signal, and outputting the demodulated signal;

an A/D converter for converting the demodulated signal to a complex digital signal;

20 a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;

25 a noise spatial eigenmatrix calculation unit for calculating a noise spatial eigenmatrix by eigenvalue factorization of the correlation matrix, one of a row and a column of the noise spatial eigenmatrix being an eigenvector belonging to a noise eigen-space;

a triangular matrix calculation unit for factorizing a matrix including a product of the noise spatial eigenmatrix and a conjugated and transposed matrix

of the noise spatial eigenmatrix to a product of one of an upper triangular matrix and a lower triangular matrix; and

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix
5 and the lower triangular matrix.

94. A directivity variable transceiver according to claim 93, wherein
the plurality of antenna elements are arranged linearly at a constant
10 interval,

said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation matrix, and

the noise spatial eigenmatrix calculation unit applies the eigenvalue
15 factorization to the unitary-transformed correlation matrix.

95. A directivity variable transceiver according to claim 91,
wherein said radio-wave arrival-direction estimating apparatus comprises:

20 an array antenna including a plurality of antenna elements;

a receiving unit for converting frequency of a **RF** signal received by each of the antenna elements in the array antenna, demodulating the converted signal, and outputting the demodulated signal;

an A/D converter for converting the demodulated signal to a complex
25 digital signal;

a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the

antenna elements;

an inverse matrix calculation unit for calculating an inverse matrix of the correlation matrix;

a triangular matrix calculation unit for factorizing the inverse matrix
5 to a product of one of an upper triangular matrix and a lower triangular matrix;

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix; and

10 an arrival-angle determination unit for determining an arrival angle based on the evaluation value by the arrival-angle evaluation unit.

96. A directivity variable transceiver according to claim 95, wherein

the plurality of antenna elements are arranged linearly at a constant
15 interval,

said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation matrix, and

the inverse matrix calculation unit calculates an inverse matrix of the
20 unitary-transformed correlation matrix.

97. A directivity variable transceiver according to claim 91,

wherein said radio-wave arrival-direction estimating apparatus comprises:

25 an array antenna including a plurality of antenna elements;

a receiving unit for converting frequency of a **RF** signal received by each of the antenna elements in the array antenna, demodulating the

converted signal, and outputting the demodulated signal;

an A/D converter for converting the demodulated signal to a complex digital signal;

a correlation matrix calculation unit for calculating a correlation
5 matrix by correlation calculation of the complex digital signal between the antenna elements;

a triangular matrix calculation unit for factorizing the correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix;

10 an inverse matrix calculation unit for calculating an inverse matrix of the one of the upper triangular matrix and the lower triangular matrix;

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the inverse matrix of the one of
15 the upper triangular matrix and the lower triangular matrix; and

an arrival-angle determination unit for determining an arrival angle based on the evaluation value by the arrival-angle evaluation unit.

98. A directivity variable transceiver according to claim 97, wherein
20 the plurality of antenna elements are arranged linearly at a constant interval,

said radio-wave arrival-direction estimating apparatus further comprises a unitary transforming unit for unitary-transforming the correlation matrix, and

25 the triangular matrix calculation unit factorizes the unitary-transformed correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix

99. A directivity variable transceiver according to claim 91,

wherein said radio-wave arrival-direction estimating apparatus comprises:

5 an array antenna including a plurality of antenna elements;

a receiving unit for converting frequency of a RF signal received by each of the antenna elements in the array antenna, demodulating the converted signal, and outputting the demodulated signal;

10 an A/D converter for converting the demodulated signal to a complex digital signal;

a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;

15 a triangular matrix calculation unit for factorizing the correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix;

20 an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix; and

an arrival-angle determination unit for determining an arrival angle based on the evaluation value by the arrival-angle evaluation unit.

100. A directivity variable transceiver according to claim 99, wherein

25 the plurality of antenna elements are arranged linearly at a constant interval,

said radio-wave arrival-direction estimating apparatus further

comprises a unitary transforming unit for unitary-transforming the correlation matrix, and

the triangular matrix calculation unit factorizes the unitary-transformed correlation matrix to a product of one of an upper triangular matrix and a lower
5 triangular matrix

101. A radio-wave arrival-direction estimating method comprising:

(a) calculating a correlation matrix of signals received by an array antenna including a plurality of the antenna elements by correlation calculation
10 between the antenna elements;

(b) calculating a noise spatial eigenmatrix by eigenvalue factorization of the correlation matrix, one of a row and a column of the noise spatial eigenmatrix being an eigenvector belonging to a noise eigen-space;

(c) factorizing a matrix including a product of the noise spatial
15 eigenmatrix and a conjugated and transposed matrix of the noise spatial eigenmatrix to a product of one of an upper triangular matrix and a lower triangular matrix;

(d) calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being
20 expressed using the one of the upper triangular matrix and the lower triangular matrix; and

(e) determining an arrival angle based on the evaluation value every predetermined angle.

25 102. A radio-wave arrival-direction estimating method according to claim 101 further comprising a step of unitary-transforming the correlation matrix between step (a) and step (b), when the plurality of antenna elements are

arranged linearly at a constant interval.

103. A radio-wave arrival-direction estimating method comprising:

- 5 (a) calculating a correlation matrix of signals received by an array antenna including a plurality of the antenna elements by correlation calculation between the antenna elements;
- (b) calculating an inverse matrix of the correlation matrix;
- (c) factorizing the inverse matrix to a product of one of an upper triangular matrix and a lower triangular matrix;
- 10 (d) calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix; and
- (e) determining an arrival angle based on the evaluation value every
15 predetermined angle.

104. A radio-wave arrival-direction estimating method according to claim 103 further comprising a step of unitary-transforming the correlation matrix between step (a) and step (b), when the plurality of antenna elements are
20 arranged linearly at a constant interval.

105. A radio-wave arrival-direction estimating method comprising:

- (a) calculating a correlation matrix of signals received by an array antenna including a plurality of the antenna elements by correlation calculation
25 between the antenna elements;
- (b) factorizing the correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix;

(c) calculating an inverse matrix of the one of the upper triangular matrix and the lower triangular matrix;

(d) calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being
5 expressed using the inverse matrix of the one of the upper triangular matrix and the lower triangular matrix; and

(e) determining an arrival angle based on the evaluation value every predetermined angle.

10 106. A radio-wave arrival-direction estimating method according to claim
105 further comprising a step of unitary-transforming the correlation matrix between step (a) and step (b), when the plurality of antenna elements are arranged linearly at a constant interval.

15 107. A radio-wave arrival-direction estimating method comprising:

(a) calculating a correlation matrix of signals received by an array antenna including a plurality of the antenna elements by correlation calculation between the antenna elements;

(b) factorizing the correlation matrix to a product of one of an upper
20 triangular matrix and a lower triangular matrix;

(c) calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix; and

25 (e) determining an arrival angle based on the evaluation value every predetermined angle.

108. A radio-wave arrival-direction estimating method according to claim 107 further comprising a step of unitary-transforming the correlation matrix between step (a) and step (b), when the plurality of antenna elements are arranged linearly at a constant interval.

5

109. A radio-wave arrival-direction estimating method comprising:

(a) calculating a correlation vector of signals received by an array antenna including a plurality of the antenna elements by correlation calculation between a reference antenna element and another antenna element;

10 (b) calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the correlation vector; and

(c) determining an arrival angle based on the evaluation value every predetermined angle.

15

110. A radio-wave arrival-direction estimating method according to claim 109 further comprising a step of unitary-transforming the correlation matrix between step (a) and step (b), when the plurality of antenna elements are arranged linearly at a constant interval.

20